

Evaluation of QMRA Assumptions Using Observational Data

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Introduction

Waterborne outbreaks are a public health concern. There is interest in Quantitative Microbial Risk Assessment (QMRA) as an approach to evaluating the risk involved by recreating in potentially contaminated water. QMRA studies rely on assumptions regarding exposure and risk obtained from the literature, unlike epidemiologic studies that rely directly on observation. From 2007-2009 the Chicago Environmental Exposure and Recreation Study (CERES) an epidemiologic study was conducted in order to evaluate the health risks by engaging in limited contact recreational activities on the Chicago Area Waterways System (CAWS) and other water ways, which includes Lake Michigan, referred to as General Use Waters (GUW). Prior to the epidemiologic study, a QMRA was performed to estimate health risks of CAWS recreation (Rijal et al. 2011). The goal of our study was to stochastically generate results which can use QMRA techniques to evaluate the risk of recreating on the CAWS using observational data collected in the CERES study.

QMRA Methods

1. Hazard Identification: identified microbes of interest which can cause diseases in humans and were measured in CERES; Pathogenic *E. coli*, *Cryptosporidium*, *Gardia lamblia*, Human Adenovirus, and Human Enterovirus. The viruses were concentrated by continuous centrifugation and quantified as per EPA Method 1623.

2. Exposure Assessment: An estimate of the dose of microbes ingested during particular recreational activities.

• Probabilistic risk assessment using Monte Carlo simulations using Crystal Ball ®



Sampling from these distributions occurred 100,000 times in order to generate an overall probability of infection for each microbe during different recreational activities

• Used observational data from the CERES study to help assess how much water is ingested during limited contact recreation (Dorevitch et al. 2011).

• Assumptions had to be made regarding the second component of the dose, microbe concentration. The assumptions included:

- 2.7% of *E. coli* measured in the water is pathogenic (Rijal et al. 2011)

• Studies have suggested that using qPCR to enumerate the number of viruses in a water sample is 34 fold log orders of magnitude greater than what is determined by culture. Since culture measures viruses capable of infecting cells, it was assumed that 1% of the virus count determined through qPCR were capable of being infectious to humans (Jiang 2006).

• The major difference between this study and other limited contact recreation QMRA studies is the assumption that only 1% of PCR enumerated viruses are capable of being infectious, and the use of observational data to determine the amount of water ingested during limited contact recreation.

3. Dose Response Analysis: Can characterize probability of infection given any dose in two different ways:

Table 1: Summary of dose-response parameters used in the QMRA (Haas et al., 1999; Mena, 2007)

Microbe	Exponential	Beta-Poisson
Human Adenovirus	$r=0.41727$	-
Human Enterovirus	$r=0.0127$	-
Cryptosporidium	$r=0.0042$	-
Giardia lamblia	$r=0.0198$	-
E. coli	-	$\alpha=0.1748, \beta=49.284$

$P(\text{infection}) = 1 - e^{-\lambda}$

$\lambda = rk/\text{dose}$, $r = 1/k$ and is calculated from the literature

Beta-Poisson: A microbe has a range of probabilities for causing an infection

$$P(\text{infection}) = 1 - \left(1 + \frac{\text{dose}}{\beta}\right)^{-\alpha}$$

When the results were calculated assuming 0.1% of qPCR measured viruses are viable, the results decreased 10 fold for the two viruses.

Summary and Limitations

A critical examination of model inputs is essential to generating valid results from a QMRA analysis. This study replaced exposure and water quality inputs of a previously-conducted QMRA with data observed in an epidemiologic study. Data related to ingestion and time of recreation for each activity was determined based on data collected during the CERES study (Dorevitch et al. 2011).

While some assumptions could be substituted with observational data, other components of the QMRA needed to be adjusted based on what was originally measured. For example, some of the microbe counts needed to be reduced in order to more accurately assess organisms which are a risk to human health. It has also been seen during preliminary research and in the literature, that qPCR produces viral particle counts much higher than the traditional culture method (Jiang, 2006). These reductions were most likely overestimates of the true concentration of viable pathogenic organisms which can be found in either the GUW or the CAWS. When the simulations were done using qPCR, the results were greatly impacted. The newer molecular techniques to rapidly detect viral particles must be further evaluated to determine its proper place in a QMRA study. This is an important clarification since the dose-response data comes from cell-culture estimates of dose, while newer measurement methods (qPCR) may over-estimate infectious virus numbers.

Despite these shortcomings, the results of the QMRA indicate that there are differences in the risk, or probability of becoming infected, among water group and most interestingly among recreational activity. The results of the QMRA are very sensitive to the microbial concentration. When the concentration of microbes was adjusted, it dramatically changed the probability of infection. These results suggest that further research into the dose-response parameters, as well as the exposure inputs could lead to more accurate conclusions. The QMRA process relies on exposure data and on dose-response data which in itself makes several assumptions. Although we found that QMRA estimates regarding duration and distribution of recreational activities and water ingestion rates to be similar to those observed in the epidemiologic study, the dose-response inputs could not be evaluated. Further work is needed to reduce the uncertainty in dose-response, particularly for viruses that are measured using different techniques than those used in the original dose-response studies.

References

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Figure 1: Map of Chicago Area Waterways (CAWS)

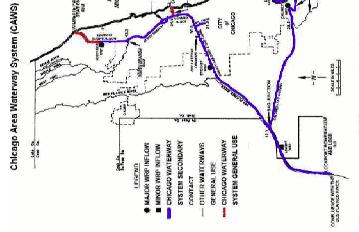


Table 2: QMRA results for each microbe by select recreational activities on the CAWS vs. GUW

Microbe	Activity*	P(infection) (per 1,000)**	P(infection) (per 1,000)*
E. coli	Kayak	2.5×10^3	1.0×10^4
	Canoe	2.5×10^3	1.0×10^4
	Fish	2.3×10^3	9.4×10^3
Cryptosporidium	Kayak	2.3×10^5	2.4×10^5
	Canoe	2.3×10^5	2.4×10^5
	Fish	2.1×10^5	2.1×10^5
Giardia lamblia	Kayak	2.1×10^2	1.4×10^4
	Canoe	2.1×10^2	1.4×10^4
	Fish	1.9×10^2	1.3×10^4
Human Adenovirus	Kayak	41	9.1×10^3
	Canoe	41	9.6×10^3
	Fish	38	8.4×10^3
Human Enterovirus	Kayak	3.0×10^2	1.9×10^4
	Canoe	2.9×10^2	2.0×10^4
	Fish	2.7×10^2	1.8×10^4

*Ingestion estimates used for kayaking and canoeing assume no capsize occurred

**Assumed median probability of infection per 1,000 exposed individuals

• When the results were calculated assuming 0.1% of qPCR measured viruses are viable, the results decreased 10 fold for the two viruses.